This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 776 011 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.05.1997 Bulletin 1997/22

(51) Int. Cl.^{6}: G11C 11/15

(21) Application number: 96117870.4

(22) Date of filing: 07.11.1996

(84) Designated Contracting States:
DE GB NL

(30) Priority: 24.11.1995 US 562482

(71) Applicant: MOTOROLA, INC.
Schaumburg, IL 60196 (US)

(72) Inventors:
- Chen, Eugene
  Gilbert, Arizona 85233 (US)
- Tehrani, Saied N.
  Tempe, Arizona 85284 (US)
- Durlam, Mark
  Chandler, Arizona 85226 (US)
- Zhu, Xiaodong T.
  Chandler, Arizona 85226 (US)

(74) Representative: Hudson, Peter David
Motorola,
European Intellectual Property Operations,
Midpoint
Alencon Link
Basingstoke, Hampshire RG21 7PL (GB)

(54) Magnetic memory and method therefor

(57) A magnetic memory utilizes a magnetic material to concentrate a magnetic field in a magnetic memory cell element. The magnetic material reduces the amount of current required to read and write the magnetic memory.

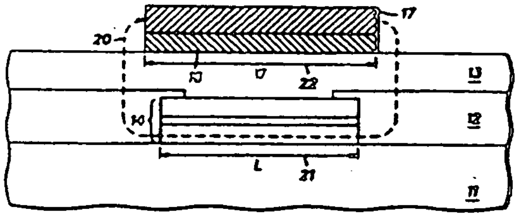


FIG. 1

EP 0 776 011 A2

Description

Background of the Invention

The present invention relates, in general, to magnetoresistive materials, and more particularly, to a novel memory using magnetoresistive materials.

In the past, a variety of magnetoresistive materials have been utilized to form non-volatile memories. Typically, such memories utilize an anisotropic magnetoresistive (AMR) or giant magnetoresistive (GMR) multilayer magnetic element as a basic memory cell element. The basic memory cell element is covered with a dielectric, and a word conductor or word line crosses the dielectric at right angles to the basic memory cell element. One problem with the prior memory is power dissipation. In order to produce a magnetic field that was sufficient to read or write the memory, a large current is required which results in high power dissipation (typically greater than 50 milliwatts/bit).

Because of the large magnetic fields (typically greater than approximately 50 oersteds) created from the large current, it is necessary to have a large distance (typically greater than the length of the memory cell) between each memory cell in order to prevent the large magnetic field from affecting nearby memory cells.

Accordingly, it is desirable to have a magnetic memory that has low power dissipation (less than 50 milliwatts/bit), that does not affect nearby memory cells when reading or writing a particular memory cell, and that does not require a large distance between memory cells.

Brief Description of the Drawings

FIG. 1 illustrates an enlarged cross-sectional portion of a magnetic memory in accordance with the present invention;

FIG. 2 illustrates an enlarged cross-sectional portion of an alternate embodiment of a magnetic memory in accordance with the present invention;

FIG. 3 illustrates an enlarged cross-sectional portion of another alternate embodiment of a magnetic memory in accordance with the present invention;

FIG. 4 illustrates an enlarged cross-sectional portion of another alternate embodiment of a magnetic memory in accordance with the present invention;

FIG. 5 illustrates an enlarged cross-sectional portion of another alternate embodiment of a magnetic memory in accordance with the present invention; and

FIG. 6 illustrates an enlarged cross-sectional portion of a magnetic memory array in accordance with the present invention.

Detailed Description of the Drawings

FIG. 1 illustrates an enlarged cross-sectional portion of a magnetic memory array or magnetic memory having a magnetic memory cell 10. The memory and cell 10 include a substrate 11 on which other portions of cell 10 are formed. Magnetic memory cell 10 includes a magnetic memory cell element 14 in which information is stored in the form of magnetization vectors within element 14. In the preferred embodiment, element 14 is a multi-layer giant magnetoresistive (GMR) material that is well known to those skilled in the art. As shown in FIG. 1, element 14 has a length 21, shown by an arrow, and a width that is oriented perpendicular to the page. A shorting bar or column conductor 12 is utilized to connect element 14 in a column with other memory cells. A dielectric 13 covers element 14 and conductor 12 in order to insulate element 14 from a word line conductor 16. Conductor 16 has a width 22, shown by an arrow, and a length that is perpendicular to the page and extends across the memory. Conductor 16 overlays element 14 and generally extends substantially perpendicular to element 14. Width 22 typically is at least equal to length 21.

A top surface of conductor 16 is covered with a magnetic material 17. Material 17 has a high permeability that allows the magnetization direction of material 17 to change in response to a magnetic field created by conductor 16. The permeability of material 17 generally is higher than the permeability of element 14. A current generally is passed through conductor 16 to create the magnetic field. As the magnetic field created by conductor 16 increases, the strength of poles accumulated at each end of material 17 also increases due to the high permeability. Consequently, the magnetic field above or on the top surface of conductor 16 is substantially zero while a magnetic field 20, indicated by an arrow, surrounding the remainder of conductor 16 is increased by an amount equal to the amount that the magnetic field above or on the top surface of conductor 16 is reduced. As a result, magnetic field 20 is concentrated toward element 14 and away from the top surface or above the top surface of conductor 16.

This increase in the intensity of magnetic field 20 reduces the amount of current required to flow through conductor 16 in order to obtain a given magnetic field intensity within element 14. The reduction in current is directly proportional to the increased intensity of the magnetic field within element 14 as a result of magnetic material 17. It is believed that material 17 can reduce the current required to produce a given magnetic field value by about fifty per cent.

Material 17 typically is formed by performing a blanket deposition of conductor material that is utilized for conductor 16, followed by a blanket deposition of the material utilized for material 17 on top of the material utilized for conductor 16. Thereafter, a mask is patterned on top of the material utilized for material 17, and the undesired portions of both materials are removed leaving conductor 16 and material 17.

FIG. 2 illustrates an enlarged cross-sectional portion of a magnetic memory cell 25 that is an alternate embodiment of memory 10 shown in FIG. 1. Portions of

FIG 2 that have the same reference numbers as FIG. 1 are the same as the corresponding FIG. 1 elements. A magnetic material 18 is formed by extending material 17 over the sides of conductor 16. Magnetic material 18 concentrates a magnetic field 19, shown by an arrow, away from the sides of conductor 16 and into element 14. This increases the intensity of field 19 by an amount equal to the intensity of the magnetic field concentrated away from the sides by material 18 and away from the top by material 17.

This increase in the intensity of magnetic field 19 reduces the amount of current required to flow through conductor 16 in order to obtain a given magnetic field intensity within element 14. The reduction in current is directly proportional to the increased intensity of the magnetic field within element 14 as a result of magnetic material 17 and magnetic material 18. It is believed that materials 17 and 18 can reduce the current required to produce a given magnetic field value by over fifty per cent.

Material 18 typically is formed by first forming conductor 16 and material 17. Then, the material utilized for material 18 is blanket deposited on top of material 17 and dielectric 13. A reactive ion etch is subsequently used to remove the material on top of conductor 16 and on top of dielectric 13 while leaving material 18 on the sides of conductor 16 and extending up to contact material 17.

FIG. 3 illustrates an enlarged cross-sectional portion of a magnetic memory cell 30 that is an alternate embodiment of cell 10 shown in FIG. 1. Portions of FIG 1 that have the same reference numbers as FIG. 1 are the same as the corresponding FIG. 1 elements. Cell 30 has a word line conductor 36 that is similar to conductor 16. However, conductor 36 may have width 23 that is larger than width 22 as will be seen hereinafter. A magnetic material 31 and a magnetic material 32 are formed on top of conductor 12 and generally overlap a portion of element 14. Materials 31 and 32 are formed at opposite ends of length 21 of element 14 so that a gap 37, shown by an arrow, is formed overlying element 14 and positioned between conductor 36 and element 14. Dielectric 13 is formed on top of materials 31 and 32. Consequently, a portion of dielectric 13 is between conductor 36 and materials 31 and 32 so that materials 31 and 32 are adjacent to conductor 36.

Materials 31 and 32 increase the intensity of magnetic fields 33 and 34, shown by arrows, formed by conductor 36 by an amount equal to the amount that materials 31 and 32 concentrate the magnetic field away from conductor 36. Gap 37 concentrates field 34 in element 14. Gap 37 has a width that is less than length 21 to assist concentrating field 34 in element 14. Width 23 generally is larger than length 21 in order to ensure that conductor 36 overlaps materials 31 and 32 so that field 33 reacts with materials 31 and 32.

FIG. 4 illustrates an enlarged cross-sectional portion of a magnetic memory cell 35 that is an another alternate embodiment of cell 10 shown in FIG. 1 and cell 30 shown in FIG. 3. Portions of FIG. 4 that have the reference numerals as FIGs. 1 and 3 are the same as the corresponding FIG. 1 and 3 elements. Because materials 31 and 32 are quite short, the increased intensity resulting from materials 31 and 32 is small when materials 31 and 32 are used alone. However, when materials 31 and 32 are used together with materials 17 and 18, gap 37 concentrates the resulting magnetic field into element 14. This resulting magnetic field is increased by the amount of the magnetic field concentrated away from above the top surface, the sides, and from a portion of the bottom of conductor 36.

FIG. 5 illustrates an enlarged cross-sectional portion of a magnetic memory cell 40 that is an another alternate embodiment of cell 10 shown in FIG. 1 and cell 30 shown in FIG. 3. Portions of FIG. 4 that have the reference numerals as FIGs. 1 and 3 are the same as the corresponding FIGs. 1 and 3 elements. Cell 40 has a magnetic material 41 and a magnetic material 42 formed on dielectric 13. Materials 41 and 42 function similar to materials 31 and 32 shown in FIG. 3. Conductor 16 is formed on materials 41 and 42. A magnetic material 44 is formed on a top surface of conductor 16, and functions similar to material 17 shown in FIG. 1. A magnetic material 43 is formed along the sides of conductor 16 and functions similar to material 18 shown in FIG. 2. Materials 41, 42, 43, and 44 create a gap 47 that functions to concentrate a magnetic field 46, shown by an arrow, created by conductor 16 away from the top, sides, and a portion of the bottom of conductor 16 and concentrates magnetic field 46 in element 14.

FIG. 6 illustrates an enlarged cross-sectional portion of a magnetic memory array or magnetic memory 50 that utilizes magnetic memory cell 10 shown in FIG. 1. Portions of FIG. 5 that have the reference numerals as FIGs. 1 and 2 are the same as the corresponding FIGs. 1 and 2 elements. Memory 50 includes a plurality of cells 10, shown by dashed boxes, that are explained in the discussion of FIG. 1. Memory 50 could also utilize cell 25 from FIG. 2 or cell 30 from FIG. 3 or cell 35 from FIG. 4 or cell 40 from FIG. 5.

It should be noted that cells 10, 25, 30, 35, and 40 could also include a digit line that assists in creating the magnetic field when the current is too large for the word or sense conductors. The digit line typically is on top of and perpendicular to the word conductor, but it could also be under the magnetic memory cell element. The magnetic material, such as material 17, could also be around the digit line in addition to or instead of conductor 16.

By now, it should be appreciated that a novel magnetic memory cell has been provided. By concentrating the magnetic field away from conductor 16 and concentrating the magnetic field in element 14, the amount of current required to produce the magnetic field is reduced. Reducing the required current reduces the amount of power dissipated by the memory. Additionally, the magnetic material elements function to reduce the effect of the magnetic field created by adjacent magnetic memory cells. This shielding effect allows the memory cells to be placed closer together without having the memory cells disturbed by the magnetic field of adjacent memory cells.

Claims

1. A method of forming a magnetic memory (10, 25, 30, 35, 40) comprising:

   forming a conductor (12) overlying a magnetic memory cell element (14); and
   concentrating a magnetic field created by the conductor (12) away from a portion of the conductor (12) and toward the magnetic memory cell element (14) wherein the magnetic field extends into the magnetic memory cell element (14).

2. The method of claim 1 wherein concentrating the magnetic field created by the conductor includes concentrating the magnetic field away from above a top surface of the conductor (12) and toward the magnetic memory cell element (14).

3. The method of claim 1 further including concentrating the magnetic field away from each side of the conductor (12) and toward the magnetic memory cell element (14).

4. The method of claim 1 wherein concentrating the magnetic field created by the conductor (12) includes concentrating the magnetic field to extend into a gap wherein the gap is between the conductor (12) and the magnetic memory cell element (14) and wherein the magnetic field extends into the magnetic memory cell element (14).

5. The method of claim 1 wherein forming the conductor (12) overlying the magnetic memory cell element (14) includes forming the conductor (12) substantially perpendicular to the magnetic memory cell element (14).

6. A magnetic memory (10, 25, 30, 35, 40) comprising:

   a substrate (11);
   a magnetic memory cell element (14) on the substrate (11);
   a conductor (12) overlying the GMR magnetic memory element (14);
   a dielectric (13) between the conductor (12) and the magnetic memory cell element (14); and
   a magnetic material (17, 18, 31, 32, 41, 42, 44) adjacent a surface of the conductor (12).

7. The memory of claim 6 wherein the magnetic material (17, 18, 31, 32, 41, 42, 44) has a permeability that is higher than a permeability of the magnetic memory cell element (14).

8. The memory of claim 6 wherein the magnetic material (17, 18, 31, 32, 41, 42, 44) is adjacent a top surface of the conductor (12).

9. A magnetic memory (10, 25, 30, 35, 40) comprising:

   a substrate (11);
   magnetic memory cell element (14) on the substrate (11);
   a conductor (12) overlying the magnetic memory cell element (14); and
   a magnetic material (17, 18, 31, 32, 41, 42, 44) adjacent a surface of the conductor (12).

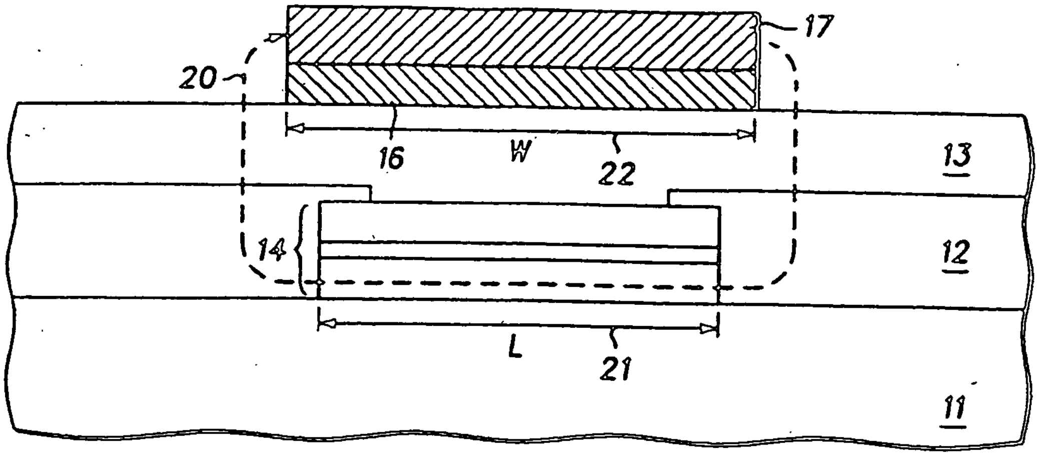


FIG. 1

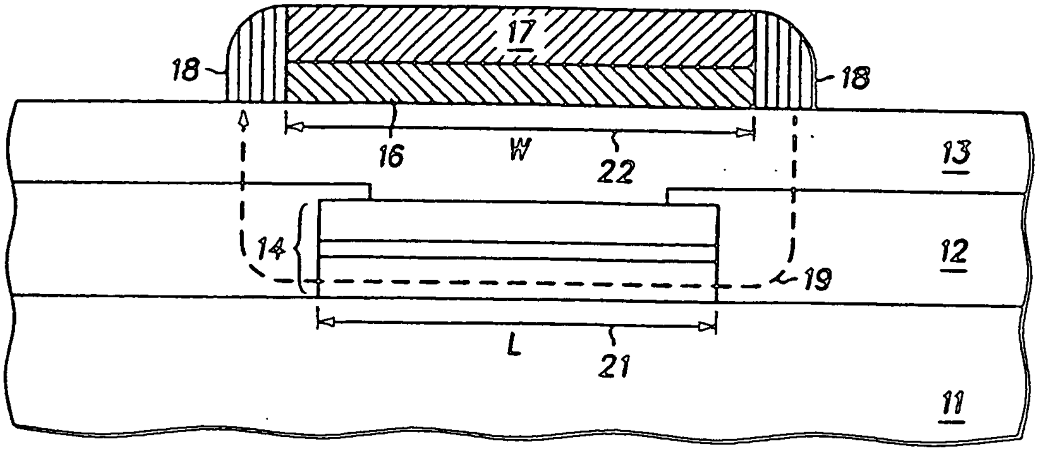


FIG. 2

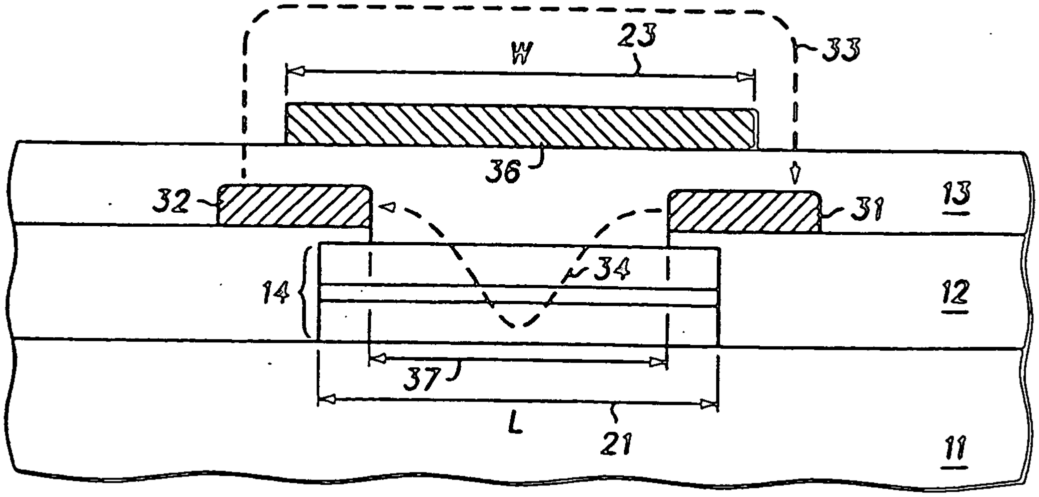
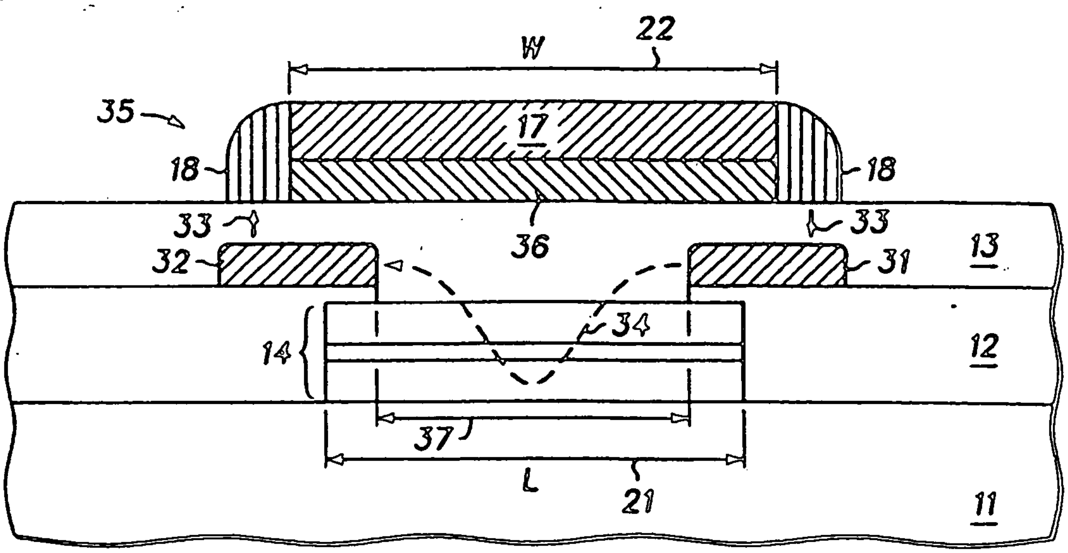
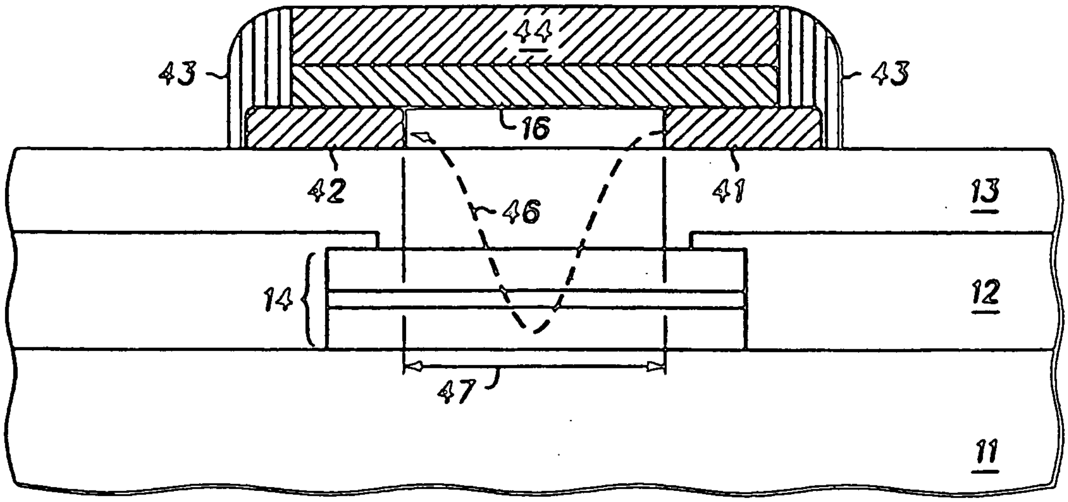


FIG. 3



35 FIG. 4



40 FIG. 5

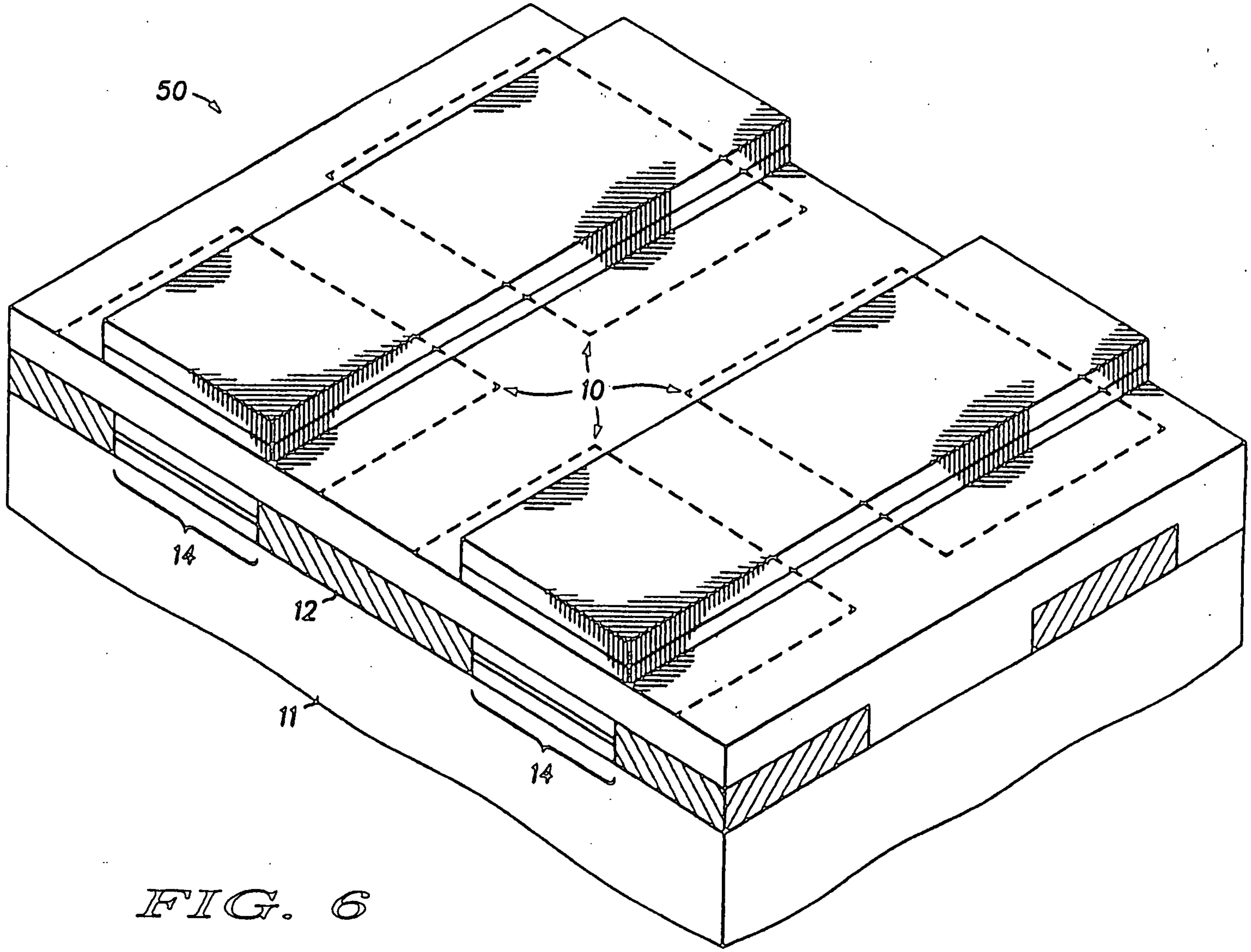


FIG. 6

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 776 011 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
19.11.1997 Bulletin 1997/47

(43) Date of publication A2:
28.05.1997 Bulletin 1997/22

(21) Application number: 96117870.4

(22) Date of filing: 07.11.1996

(51) Int. Cl.^{6}: G11C 11/15

(84) Designated Contracting States:
DE GB NL

(30) Priority: 24.11.1995 US 562482

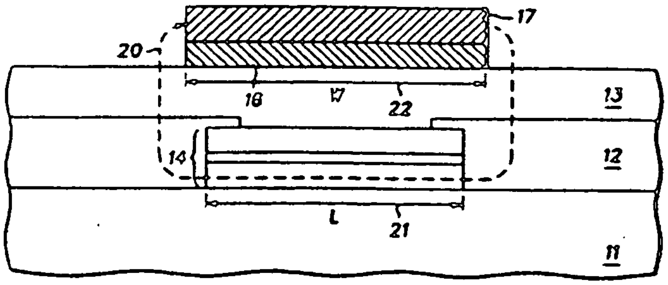
(71) Applicant: MOTOROLA, INC.
Schaumburg, IL 60196 (US)

(72) Inventors:
- Chen, Eugene
  Gilbert, Arizona 85233 (US)
- Tehrani, Saied N.
  Tempe, Arizona 85284 (US)
- Durlam, Mark
  Chandler, Arizona 85226 (US)
- Zhu, Xiaodong T.
  Chandler, Arizona 85226 (US)

(74) Representative:
Hudson, Peter David
Motorola,
European Intellectual Property Operations,
Midpoint
Alencon Link
Basingstoke, Hampshire RG21 7PL (GB)

(54) Magnetic memory and method therefor

(57) A magnetic memory utilizes a magnetic material to concentrate a magnetic field in a magnetic memory cell element. The magnetic material reduces the amount of current required to read and write the magnetic memory.



10 FIG. 1

EP 0 776 011 A3

Printed by Rank Xerox (UK) Business Services
2.14.23/3.4

European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 7870

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 173 873 A (WU ET AL.) * abstract * * column 2, line 41 - column 5, line 23; figures 1-3 * ---	1,6	G11C11/15
A	EP 0 248 355 A (HONEYWELL INC.) * abstract * * column 3, line 15 - column 14, line 35; figures 1-3 * ---	1,6	
A	IE.E.E. TRANSACTIONS ON COMPONENTS, PACKAGING AND MANUFACTURING TECHNOLOGY: PART A., vol. 17, no. 3, September 1994, NJ US, pages 373-379, XP000462470 BROWN ET AL.: "1 MB MEMORY CHIP USING GIANT MAGNETORESISTIVE MEMORY CELLS" * page 373, left-hand column, line 1 - page 376, left-hand column, line 15; figures 1-9 * -----	1,6	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

G11C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 September 1997	Stecchina, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document